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ABSTRACT

This instructor's guide on hydraulics is part of a series of individualized instructional materials. The guide is provided to help the instructor make certain that each student gets the most benefit possible from both the student's manual and what he/she does on the job. Notes for the instructor contain suggestions on how the student should use the student's manual. Other contents of the guide include answers to exercise questions and assignment test questions, one set of assignment tests, a program record, and a work sheet that the instructor can use to relate instruction to job experience for the student. Topics covered are liquid flow, pressure gauges and volume meters, and hydraulic pumps, valves, cylinders, motors, accumulators, and liquids. (YLB)

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Introduction to Hydraulics

Instructor's Guide

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Foreword

This publication is one of a series of individualized instructional materials. Students using this material can work at their own pace, enabling them to concentrate on areas that best fit specific needs. The design of the instruction makes it possible to relate work experience with materials studied at school.

Although the material is designed for individualized study, it should be used under the supervision of an instructor. For that reason, two basic publications are offered—a student's manual and an instructor's guide.

The *student's manual* is for the use of the person in training. It is self-contained. Each assignment has the information needed, a list of objectives that should be met, and exercise questions that can help the student meet those objectives.

The *instructor's guide* has additional information that may help the instructor help the student. There are suggestions on how the student should use the student's manual and how the instructor can coordinate work experience and classroom study. The instructor's guide also contains (1) answers to exercise questions and assignment test questions, (2) one set of assignment tests, and (3) a work sheet that the instructor can use to relate instruction to job experience for the student.

Although both publications are copyrighted, an instructor should feel free to make copies of the assignment tests and work sheet. If the instructor prefers, copies of these same sheets can be ordered separately for individual students from Extension Instruction and Materials Center, The University of Texas at Austin, P. O. Box 7218, Austin, Texas 78712.

Jack E. Robertson, Ph.D.
Director, Extension Instruction
and Materials Center

Notes for the Instructor

The student's self-contained manual is designed for use in presenting related technical information to (1) groups of trade and industrial students with diversified vocational objectives and (2) homogeneous groups in which the learning level of individual students vary considerably. The manual is not intended to be used as a type of *correspondence* course but must be used by students under the direct supervision of an instructor.

This guide is provided to help make certain that each student gets the most benefit possible out of both the student's manual and what is done on the job. The notes in this section are part of that assistance. In addition, this guide provides answers to assignment exercises, answers to assignment test questions, and a work sheet to help in coordinating work experiences and assignments in the manual.

These notes and all answers to question should be retained by the instructor. The actual assignment tests and the work sheet can be removed from this book in order to make it easier to use or reproduce them. For greater convenience, this guide is punched for notebook use.

Academic Background

English. The student should be able to read at the tenth-grade level in order to comprehend the information in this manual. However, after entering the trade, specifications of various units and service manuals will require that the student's reading level be at least at the twelfth grade.

Science. A junior high science course would be beneficial in helping the student understand Btu, specific heat, latent heat, pressure and temperature relationships, and other physical laws.

Aptitudes. A high mechanical aptitude and high degree of manual dexterity are required to develop the proficiency required in order to be successful.

The preceding information may be used in counseling students who express a desire to train in this field. It also could be useful to school counselors, teachers, and others who may have the opportunity to guide students who wish to enter a vocational program.

Assignment Design and Teaching Principles

Each assignment in the student's manual is designed to use as many fundamental teaching principles as possible. For that reason, each assignment is broken down into four parts—objectives, technical information, exercise, and test.

Objectives. The first teaching principle is that the student should be informed at the outset what is to be learned from the assignment. The statement of objectives for an assignment is based on this principle. These are performance objectives that can be tested when the assignment is completed.

Technical Information. The second principle is that technical information should be presented in a complete but concise form. All the information needed to complete the assignment exercise and meet the objectives is presented in the second main part of the assignment. This information has been organized to assist the learner—either step by step, by moving from simple to complex, by going from familiar to unfamiliar, or by using logical topics and subtopics. Of the four teaching

principles discussed here, this is by far the most important. After all, the technical information is what should be learned. The biggest favor the instructor can do for the student is to instill the idea that if the information is learned, the grades will take care of themselves.

Exercise. The third principle is that technical information is learned better if it can be applied as soon as possible after presentation. This is accomplished by the use of an exercise for each assignment. The questions are phrased to emphasize key points, to aid in learning facts that must be memorized, or to provoke thought and evaluation of the technical information. The instructor should emphasize to students that both objectives and technical information should be read before they attempt to answer the exercise questions. An exercise is not an open-book test, and this idea should be discouraged. Answers in this guide may be useful when helping a student who is having difficulty with an assignment exercise. Difficulty in locating information usually results from a student's failure to study charts, diagrams, and similar matter. Questions are directed to all the different types of information given in an assignment, and this should encourage the student to study the assignment more fully.

Test. The fourth major principle is that the effectiveness of an assignment should be evaluated. This is made possible by brief assignment tests provided in this guide. A test should be given when an assignment is completed. Each assignment test is based on the objectives stated for that assignment.

Answers to both assignment exercises and assignment tests have been made brief as possible, to facilitate rapid and accurate checking of the student's classroom work. All answers should be retained by the instructor for obvious reasons.

Tests and Work Sheet

The last section of this book has been placed after a divider page, so that the tests and work sheet can be removed for use with individual students or for reproduction. The actual tests and work sheet can be reproduced without the publisher's permission. Sets of this material can also be ordered separately.

A work sheet is provided for the convenience of the instructor in (1) planning how job experience is to be matched to related instruction in the student's manual and (2) keeping daily records as the student progresses through the year. The work sheet is deliberately designed so the instructor can follow any sequence of instruction desired. The assignments are coded and can easily be listed opposite the desired jobs. Also, enough space is provided for other records that the instructor may wish to include on the work sheet.

Answers to Exercises

Exercise 1

How to Use This Manual

1. Both want learning to be easy.
2. (1) the objectives
   (2) the technical information
   (3) the exercise
   (4) the test
3. They tell you what information is important and what you should be able to remember.
4. They tell you what to look for on the test.
5. (1) Read the objectives.
   (2) Read the technical information.
   (3) Answer the exercise questions.
6. to learn the most from the assignment
7. how much you learn
8. because you will have been over the information tested three times

Exercise 2

Introduction

1. the study of the physical behavior of all liquids, particularly oils in present-day hydraulic systems
2. to transmit force from one point to another and to multiply force
3. (1) The different parts can be located at widely separated points.
   (2) Hydraulic systems are economical to operate.
   (3) Force can be multiplied through the selection of different sizes of cylinders and pistons.
   (4) Hydraulic systems are more compact than other systems.
   (5) Hydraulic systems are safer than mechanical systems.
4. by conforming to the shape of their containers
5. Liquids are less compressible than most solids.
6. Pressure is exerted equally in all directions at right angles to the inside wall.
7. Pressure equals force divided by the area over which the pressure is distributed.
8. by selecting the proper sizes of cylinders and pistons
9. When force is multiplied by any amount, the travel distance of the piston exerting the force must be multiplied by the same number.
10. They are exactly equal.

Exercise 3

Liquid Flow

1. *Volume* is the quantity of liquid that will pass a given point in a hydraulic system in a given unit of time.
2. in gallons per minute
3. *Velocity* is the rate or speed at which the liquid is moving past a particular point in the system.
4. in feet per second
5. because they are interrelated
6. one in which the liquid flows at a constant rate
7. one in which the liquid flows in a straight line without rolling and tumbling in swirls and eddies
8. one in which the liquid does not flow evenly but has swirls, eddies, and cross motions as it flows
9. curvature of bends, roughness of the pipe, or the number of bends in the pipe
10. one that has a radius of not less than 2½ to 3 times the inside diameter of the pipe
11. the tendency of an object (or mass) to resist being set in motion if it is at rest and to resist any change in its rate of motion or direction of motion if it is already in motion
12. the mass of the liquid and the work to be done
13. gravity, inertia, and friction
14. They direct the liquid to the proper pipe and working parts.

Exercise 4

Pressure Gauges and Volume Meters

1. As pressure builds up inside, it attempts to straighten out.
2. Tip travel is directly proportional to the amount of pressure inside the element.
3. It is easier to manufacture in uniform quality and large quantity. It also occupies less space.
4. They provide much greater movement or tip travel.
5. by using levers or gears
6. There is less lost motion and friction to interfere with accurate gauging of pressures.
7. The first tube is mounted in an upright position, and the second tube is mounted 180° from the first tube. The pressures cause the two tubes to pull against each other.

8. the energy from the flowing liquid
9. (1) a ball-like center section
   (2) a pin
   (3) a disk
10. over and under the piston or disk
22. (1) by rotating the cam in a stationary cylinder housing
    (2) by rotating the cylinder housing around a stationary shaft
23. at the outer end of the pistons
24. at the center of the rotating cylinder

Exercise 5
Hydraulic Pumps

1. a device through which an external force can be transferred to a liquid
2. to do work
3. (1) positive-displacement pump
   (2) non-positive-displacement pump
4. The pump will be destroyed.
5. the force of more liquid being deflected into the hydraulic system
6. that the piston moves back and forth
7. check valves
8. (1) external gear pump
   (2) internal gear pump
   (3) rotor-type pump
   (4) lobe pump
   (5) rotating plunger pump
9. the tendency of any object to move away from the center when it is rotated
10. from the center to the outside
11. between the teeth of the gears on the outside next to the housing
12. to form a seal with the teeth and to separate the intake side from the discharge side of the pump chamber
13. the lobes themselves
14. The outer gear has one more lobe than the inner gear.
15. between the edge of the vanes and the housing
16. to increase the size of the chamber on the intake side and reduce it on the discharge side
17. a swashplate
18. at an angle
19. (1) by rotating the cylinder and pistons across a stationary swashplate
    (2) by rotating a swashplate across the pistons
20. to increase efficiency and produce a more constant flow of liquid
21. The cylinders are mounted at an angle to the rotating plate to which the pistons are connected.

Exercise 6
Hydraulic Valves

1. They control the pressure, direct the fluid to the proper circuits, and regulate the volume of liquid to each circuit.
2. They limit the pressure in a hydraulic system, unload the excess liquid from the pump, and regulate the pressure at which liquid enters a circuit.
3. to prevent the hydraulic system from developing pressure above a given amount
4. a valve, a seat, and a spring
5. buttons, small cones, or disks
6. to handle large volumes where there must be little difference in pressure between the point at which the valve opens and when it closes
7. when the main circuit delivers high or fluctuating pressures even though a branch of the circuit requires a lower constant pressure
8. (1) constant reduced pressure valve
   (2) fixed amount reduction valve
9. to direct liquid from one branch of a circuit to another branch after the needs of the first branch are filled
10. to dump liquid back into the reservoir at low pressure after the system pressure has been reached
11. a relief valve
12. to move liquid in one direction
13. by aligning ports in the housing with matching holes in a cylinder
14. (1) its adaptability
    (2) its compactness
15. by adding lands and ports
16. to prevent buildup of pressure on one end that would prevent the spool from moving in either direction
17. to prevent liquid pressure from forcing the spool in one direction

18. (1) open-center
(2) closed-center
19. It flows back to the reservoir.
20. an unloading valve
21. by restricting liquid or by diverting parts of the flow back to the reservoir
22. pressure (and volume) changes in the liquid supply circuit
23. a sliding cylinder with a metered orifice
24. to separate the flow of a single circuit into two branches
25. the size of the face of the spool on each side of the valve
26. to turn the liquid supply on and off
27. a screw
28. a tapered plug, ball, or disk
29. to allow liquid to flow in one direction only

Exercise 7
Hydraulic Cylinders

1. to convert hydraulic or liquid fluid power back into mechanical energy
2. (1) a straight back-and-forth movement
(2) a rotary back-and-forth movement
3. a return spring or gravity
4. to prevent air buildup or a vacuum from developing
5. Liquid pressure operates in only one direction in a single-acting cylinder, while it operates in both directions in a double-acting cylinder.
6. to limit the piston travel
7. by closing the discharge port and trapping liquid in the cylinder
8. to protect the cylinders from the impact of sudden stops
9. two small discharge ports rather than one large one
10. The piston covers first one port and then the other. Covering the first port slows the piston because the liquid flow is reduced.
11. one to the cylinder wall and the other to the shaft
12. to separate the cylinder interior into two compartments
13. The fixed vane forms a seal with the shaft. The shaft vane forms a seal with the inside cylinder surface.

Exercise 8
Hydraulic Motors

1. A pump drives its liquid while a motor is driven by its liquid.
2. at the inside wall of the motor housing and at the point at which the two gears mesh
3. to separate the intake compartment from the discharge compartment
4. the difference between the high intake pressure and the low discharge pressure
5. a crescent
6. the external gear
7. a rotor and a rotor ring
8. the meshing of one rotor lobe and the other lobes sliding along the outer surface of the rotor ring
9. The increased volume of liquid on the side with the extended vanes exerts more pressure.
10. the swashplate
11. the swashplate
12. the tendency of the piston to slide down the swashplate
13. It is eccentric or offset.
14. the piston sliding along the surface of the casing as pressure is exerted above the piston

Exercise 9
Hydraulic Accumulators

1. (1) absorb shock
(2) store energy
(3) maintain constant pressure
2. The momentum of the liquid continues even though there is no place for the liquid to go.
3. because liquid is not compressible
4. by allowing the liquid to flow into it as the resistance builds
5. by storing liquid during high-pressure periods and releasing it during low-pressure periods
6. It is a container that permits liquid to flow into it under pressure.
7. when the pressure buildup in the hydraulic system equals the weight on the accumulator
8. pressure equal to the weight on the accumulator
9. A spring provides the resistance rather than a weight.

10. when liquid pressure begins to exceed the spring resistance
11. by supplying liquid when the pressure begins to drop as a result of the device being activated
12. (1) piston-type accumulators
    (2) bladder-type accumulators
    (3) diaphragm-type accumulators
13. the amount of gas in the gas chamber
14. because otherwise the liquid would absorb the gas in time
15. an inert dry gas such as nitrogen
16. to prevent the bladder from being forced through the liquid inlet during low-pressure periods
17. A metal element is used to separate the gas from the liquid in a diaphragm-type accumulator.

Exercise 10
Hydraulic Liquids

1. the fact that they are not compressible
2. Its film strength is not great enough to resist being wiped or squeezed out from between the surfaces.
3. under a wide range of temperatures and under severe weather conditions
4. It loses its ability to lubricate and to form seals and is more prone to leak.
5. It resists flow, cannot get in between the close tolerance parts, and causes power loss and higher operating temperatures.
6. It causes it to become thinner and to flow faster.
7. the Saybolt Universal Viscometer
8. that the liquid has a great difference in thickness between the low and high temperatures
9. oxidation, rust, corrosion, foaming, acids, and sludges
10. organic acids
11. sludges in the system
12. If more air enters the liquid than it can absorb, bubbles will be formed. The churning and swirling of the liquid then causes the bubbles to develop into a foam.
13. Operation will be mushy and difficult to perform correctly. Also, foam reduces the ability of the liquid to lubricate.
14. acids, sludges, rust, and oxidation
15. Additives are used in the liquid.
16. Store the liquid in clean containers in a clean area. Use clean tools when filling the system. Use a clean cloth to wipe the dipstick when checking the system.
17. Wipe dirt and grease from filler caps or dipsticks. Steam-clean or use solvents to clean the machine before removing any part from the hydraulic system. Plug or cover any disconnected lines while working on the machine.

Answers to Assignment Tests

Test 1
How to Use This Manual
1. technical information
2. objectives
3. objectives
4. three

Test 2
Introduction
1. cylinders / pistons
2. containers
3. right
4. travel distance

Test 3
Liquid Flow
1. Velocity
2. turbulent
3. Inertia
4. gravity / inertia / friction

Test 4
Pressure Gauges and Volume Meters
1. straighten out
2. Tip travel
3. levers
4. liquid
5. piston (disk)

Test 5
Hydraulic Pumps
1. force
2. Reciprocating
3. External gear
4. crescent
5. one lobe
6. swashplate

Test 6
Hydraulic Valves
1. relief
2. Pressure-reducing
3. unloading
4. compactness
5. open / closed
6. Proportional flow dividers

Test 7
Hydraulic Cylinders
1. rotary
2. single / double
3. trapping
4. fluid cushion
5. two

Test 8
Hydraulic Motors
1. teeth (or gears) mesh
2. chambers
3. rotor / rotor ring
4. swashplate

Test 9
Hydraulic Accumulators
1. store energy
2. compressible
3. resistance
4. gas / gas

Test 10
Hydraulic Liquids
1. compressible
2. form seals
3. high
4. moisture
5. Additives

Assignment Tests and Work Sheet

for

Introduction to Hydraulics

For Your Convenience . . .

- Pages in this section may be reproduced *without permission* by any instructor for teaching purposes.
- Instructors who do not want to reproduce the material can purchase separate sets of just this section from Extension Instruction and Materials Center, The University of Texas at Austin, P. O. Box 7218, Austin, Texas 78712.
- Each assignment test is based on a specific assignment.
- The work sheet is provided for use as a weekly log if the instructor desires. On the sheet is a list of the contents of the student's manual, for coordinating assignments with work experiences.

TEST 1

How to Use This Manual

1. The four parts of an assignment are: (1) the objectives, (2) the _____ _____, (3) the exercise, and (4) the test.

2. The _____ tell you what is important to learn in the assignment.

3. The first thing to read is the _____.

4. The test should be a snap because you will have been over the information _____ times.

TEST 2

Introduction

---

1. Force can be multiplied by the selection of different sizes of _____ and _____.

2. Liquids conform to the shape of their _____.

3. Pressure is distributed equally in all directions and at _____ angles to the inside wall.

4. When force is multiplied by any amount, the _____ _____ of the piston exerting the force must be multiplied by the same number.

TEST 3

Liquid Flow

---

1. _____ is the rate or speed at which the liquid is moving past a particular point in the system.

2. A _____ flow is characterized by eddies and swirls.

3. _____ is the tendency of any object to resist being set in motion or to have its motion changed.

4. An energy source in a hydraulic system must overcome _____, _____, and _____, in addition to supplying enough power to do the work.

TEST 4

Pressure Gauges and Volume Meters

---

1. As pressure builds up inside a Bourdon tube element, it tends to _____ _____.

2. _____ _____ is directly proportional to the amount of pressure inside the element.

3. Gears or _____ are used to increase the motion of C-tubes.

4. A nutating piston meter uses the energy from the _____ to operate the indicating mechanism.

5. Liquid flows over and under the _____ _____ in the nutating piston.

TEST 5

Hydraulic Pumps

1. A pump is a device through which an external _____ can be transferred to a liquid.

2. _____ pumps are those that have a piston that moves back and forth.

3. _____ _____ pumps carry the liquid from the intake side to the discharge side in the space between the teeth.

4. A _____ is used on internal gear pumps to separate the intake side from the discharge side and to form a seal.

5. Rotor pumps use an internal gear and an external gear with the internal gear having _____ _____ more than the external gear.

6. Axial piston pumps move the pistons by rotating the _____ or by having the plate stationary and then moving the cylinders.

TEST 6

Hydraulic Valves

1. A _____ valve limits the pressure that can be developed in a hydraulic system.

2. _____ valves maintain a constant pressure even though the main circuit pressure fluctuates.

3. An _____ valve dumps fluid back to the reservoir when operating pressure has been reached in the circuit.

4. The two most important features of spool valves are their adaptability and _____.

5. All spool valves are either _____-center or _____-center valves.

6. _____ _____ _____ separate the flow of a single circuit into two branches.

TEST 7

Hydraulic Cylinders

1. Hydraulic cylinders produce a straight back-and-forth movement and a _____ back-and-forth movement.

2. All cylinders are either _____-acting or _____-acting.

3. Automatic stops limit the travel of pistons by _____ liquid in the cylinder.

4. A _____ _____ is used to protect cylinders from the impact of sudden stops.

5. Vane cylinders use _____ vanes.

TEST 8

Hydraulic Motors

1. External gear motors have two gears that form a seal with the motor housing wall and at the point where the _____ _____.

2. The importance of the seal made by the moving parts of a motor is that two _____ are separated from each other.

3. The moving parts of a rotor-type internal gear motor are a _____ and a _____ _____.

4. A _____ converts the back-and-forth motion of the piston to twisting motion, in an axial piston motor.

TEST 9

Hydraulic Accumulators

1. Accumulators absorb shock, _____ _____, and maintain constant pressure.

2. An accumulator is required because liquid is not _____.

3. Liquid flows into an accumulator when the hydraulic pressure begins to exceed the _____ in the accumulator.

4. Resistance in a pneumatic accumulator is determined by the amount of _____ in the _____ chamber.

TEST 10

Hydraulic Liquids

1. Liquid is a good agent for transmitting power from one point to another because it is not _____.

2. A liquid that is too thin loses its ability to lubricate and to _____ _____.

3. A good hydraulic liquid has a _____ Viscosity Index number.

4. Air and _____ both produce acids when absorbed by the liquid.

5. _____ are used to help liquids resist absorbing air and moisture.

CONTENTS OF STUDENT'S MANUAL

1. How to Use This Manual
2. Introduction
3. Liquid Flow
4. Pressure Gauges and Volume Meters
5. Hydraulic Pumps
6. Hydraulic Valves
7. Hydraulic Cylinders
8. Hydraulic Motors
9. Hydraulic Accumulators
10. Hydraulic Liquids

WORK SHEET

FOR COORDINATING JOBS WITH RELATED INSTRUCTION USING

INTRODUCTION TO HYDRAULICS

This form is for your convenience in planning and keeping records of training. Contents of the student's manual are at the left. The columns below provide space for listing job experiences for the individual student and assignment numbers and other references related to each job. Blanks are large and divided by days so the teacher and student can list other information that might be useful in a weekly log.

Student _____

Training Station _____

JOB EXPERIENCES	RELATED INSTRUCTION
Monday Work Hrs:	
Tuesday Work Hrs:	
Wednesday Work Hrs:	
Thursday Work Hrs:	
Friday Work Hrs:	